High Efficiency and High Rate Deposited Amorphous Silicon-Based Solar Cells

PHASE III Fourth Quarter
Technical Progress Report

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Amorphous Silicon Based Minimodules with Silicone Elastomer Encapsulation

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Introduction

Ethyl vinyl acetate (EVA) is the most commonly used material for the encapsulation of terrestrial solar cells. It is well known that EVA turns yellow upon extended exposure to ultraviolet light. This yellowing upon exposure to UV light is a characteristic of most carbon based polymers. Silicon-based polymers (silicones) may not show this effect. Although silicones were used to encapsulate solar cells in the 1970s and 1980s, they were dropped in favour of ethyl vinyl acetate due to its lower cost [1]. However, the price of silicone elastomers has come down over the years and their quality and ease of application have improved, which may make them suitable for encapsulating solar cells once again. We have recently fabricated 4"x 4" and 4"x8" minimodules encapsulated with a combination of a silicone elastomer and Dupont Tefzel.

Experimental Details

The silicone used in our experiments was Dow Corning's Sylgard 182. Sylgard 182 is a blend of silanes $(\text{-Si-})_n$ and siloxanes $(\text{-Si-O-Si-})_n$ with alkyl groups substituting some of the hydrogen atoms, i.e. it has a silicon backbone, which makes it different from carbon based polymers such as EVA. Glass slides were encapsulated on both sides with EVA/Tefzel and silicone elastomer/Tefzel in a vacuum laminator. The EVA was obtained from Specialized Technology Resources. Figure 1 compares the light transmission of these samples with that of a plain glass slide.

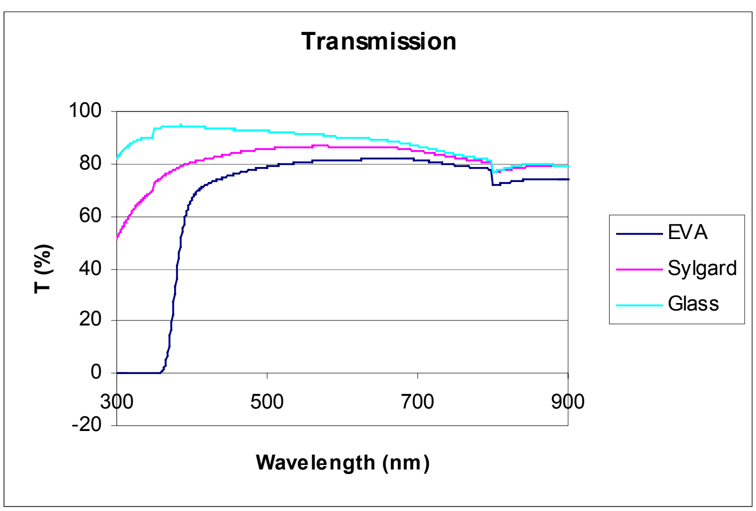

Figure 1: Transmission of glass encapsulated with EVA and Sylgard.

In the thickness applied, the Sylgard-encapsulated slide showed better light transmission throughout the visible wavelength range than the EVA encapsulated slide. Its UV cutoff was more gradual than that of EVA, which blocked all light of wavelength shorter than 360 nm.

Two minimodules were then fabricated from 4”x4” single junction amorphous silicon-germanium solar cells and encapsulated with Sylgard 182 and Tefzel in the vacuum laminator. The first minimodule had a single 4”x4” a-SiGe n-i-p cell while the second consisted of two 4”x4” cells in series. Each cell had an active area of approximately 81 cm^2. Current collection grids consisting of tinned copper wire applied to the ITO front contact with conductive silver paint for the series interconnected cells, and conducting graphite paint for the single cell. Reverse-protection diodes were also attached between the bus bars of the cells. Before application of grids, the cells were shunt-passivated using a light-assisted electrochemical method [2], details of which will be reported separately. The cells were then vacuum laminated with Sylgard 182 and Tefzel at 125°C for 30 minutes. Being a liquid, Sylgard 182 flows well, and no trapped bubbles were found in the laminated minimodules. Coverage of raised features (e.g. the diodes and grid lines) was excellent. Figure 2 shows a photo of the 4”x4” and 4”x8” minimodules. The discolouration on the surface of the cells is a result of the shunt passivation process.

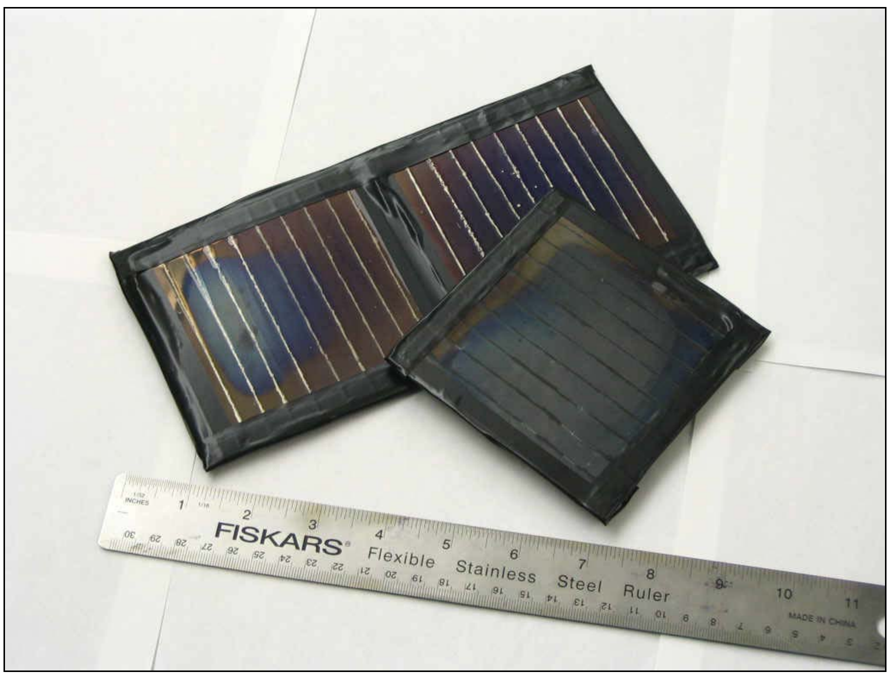

Figure 2: Silicone elastomer encapsulated a-SiGe based minimodules

The cells produced the expected open circuit voltages of 0.8 V and 1.6 V for the single and two-cell minimodules, respectively. The short circuit current was 183 mA for the 4”x4” minimodule, and 760 mA for the 4”x8” interconnected minimodule, corresponding to current densities of 2.2 and 9.4 mA/cm^2, respectively. The currents were limited by the series resistance of the grids and interconnects, which at approximately 1 Ω per cell for the silver paint-attached grids and 4 Ω per cell for the carbon paint-attached grids, were excessive for the expected I_{sc} of ~1.6A. With the reverse protection diodes removed and under a reverse bias, the current in the 4”x8” minimodule increased to approximately 1.0A.

Conclusion

Both minimodules encapsulated with silicone elastomer functioned well. The quality of the encapsulant in terms of adhesion and bubble-free lamination was found to be good. Its light transmission for the thickness applied was found to be better than that of EVA. We conclude that silicone elastomers can be used as an alternative encapsulant for encapsulating solar cells.

References

[1] Muirhead, I.J. and Hawkins, B.K., *An assessment of photovoltaic power in the Telstra network*, Annual Conference of the Australian and New Zealand Solar Energy Society – SOLAR, 1995

[2] Vijh, A. and Deng, X., *Light Assisted Shunt Passivation for Amorphous Silicon Photovoltaics,* Patent Application submitted to USPTO, April 2004.